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Rapid detection of fear in body expressions

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RESEARCH****Research Report****Rapid detection of fear in body expressions, an ERP study****C.C.R.J. van Heijnsbergen^a, H.K.M. Meeren^a, J. Grèzes^c, B. de Gelder^{a,b,*}**^aCognitive and Affective Neuroscience Laboratory, Tilburg University, Tilburg, The Netherlands^bAthinoula A. Martinos Center for Biomedical Imaging, Massachusetts General Hospital, Harvard Medical School, Charlestown, MA, USA^cLaboratoire de Physiologie de la Perception et de l'Action (LPPA), CNRS - Collège de France, Paris, France

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ABSTRACT

Recent findings indicate that the perceptual processing of fearful expressions in the face can already be initiated around 100–120 ms after stimulus presentation, demonstrating that emotional information of a face can be encoded before the identity of the face is fully recognized. At present it is not clear whether fear signals from body expressions may be encoded equally as rapid. To answer this question we investigated the early temporal dynamics of perceiving fearful body expression by measuring EEG. Participants viewed images of whole body actions presented either in a neutral or a fearful version. We observed an early emotion effect on the P1 peak latency around 112 ms post stimulus onset hitherto only found for facial expressions. Also consistent with the majority of facial expression studies, the N170 component elicited by perceiving bodies proved not to be sensitive for the expressed fear. In line with previous work, its vertex positive counterpart, the VPP, did show a condition-specific influence for fearful body expression. Our results indicate that the information provided by fearful body expression is already encoded in the early stages of visual processing, and suggest that similar early processing mechanisms are involved in the perception of fear in faces and bodies.

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1. Introduction

To act effectively and adaptively, observers must rapidly perceive relevant signals provided by the physical and social environment, foremost among them facial expressions and body language. Recent investigations using psychophysical methods and brain imaging techniques have already revealed important similarities between the visual encoding of faces and bodies and the question now arises whether these similarities also extend to the time course of emotional body perception.

Perception of faces and bodies is based upon dedicated neural structures. Many studies have reported that an area in mid-fusiform cortex is selectively sensitive to faces (Haxby et al.,

1994). Selective activations elicited during body perception have been revealed within another neural area, near the middle occipital gyrus, the so-called extrastriate body area (EBA) (Downing et al., 2001; Grossman and Blake, 2002; Peelen and Downing, 2005; Sakreida et al., 2005; Spiridon et al., 2006). More recently however, it was shown that an area in the mid-fusiform cortex is also selectively activated in response to whole bodies (Peelen and Downing, 2005; Schwarzlose et al., 2005; Spiridon et al., 2006).

Faces and bodies are equally sensitive to canonical orientation as recognition is disrupted when they are shown upside down (Reed et al., 2003; Valentine, 1988). Regarding the temporal dynamics associated with the perception of faces

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Abbreviations: ERP, Event Related Potential; PSO, Post Stimulus Onset; VPP, Vertex Positive Potential

and bodies, important similarities in electrophysiological correlates have been revealed. The N170, a well-known negative ERP component peaking around 170 ms at occipito-temporal sites, which has been associated with the structural encoding stage of processing faces (Bentin et al., 1996; Bruce and Young, 1986; Eimer, 2000a), has recently been shown to be elicited by whole body images with faces removed or blurred (Gliga and Dehaene-Lambertz, 2005; Meeren et al., 2005; Stekelenburg and de Gelder, 2004; Thierry et al., 2006). Most importantly however the electrophysiological inversion effect (Eimer, 2000b; Itier and Taylor, 2002; Watanabe et al., 2003), a delayed and enhanced N170 deflection for inverted stimulus presentation, was elicited by both faces and bodies in contrast to control objects (Stekelenburg and de Gelder, 2004). Behavioral data (Slaughter et al., 2004) have recently been obtained showing sensitivity for the canonical properties of faces and bodies alike at around 18 months. These results are supported by ERP recordings providing evidence that the configuration of faces and bodies is already processed at 3 months of age (Gliga and Dehaene-Lambertz, 2005).

The above results all concern neutral face and body images. A more challenging picture emerges however when we turn to results obtained using facial and bodily expressions of emotion. With respect to the functional neuro-anatomy we found that the fusiform cortex and amygdala play an important role in processing fearful body expressions (de Gelder et al., 2004, 2006; Hadjikhani and de Gelder, 2003) as was previously shown for fearful face expressions (Dolan et al., 2001; Morris et al., 1998; Rotshtein et al., 2001). This original finding has now been confirmed in other studies using upper body parts (Grosbras and Paus, 2005) and whole bodies (Grèzes et al., 2007; Van de Riet et al., submitted for publication). In contrast, the MT/V5/EBA area is only sensitive to body shapes in line with what was originally reported but not to emotional expressions of the body (Van de Riet et al., submitted for publication).

An EEG study by Meeren et al. (2005) investigating the temporal dynamics of the combined processing of facial and bodily expressions revealed behavioral and rapid electrophysiological effects of emotional congruency. Already at 110 ms post stimulus onset (PSO), the P1, a positive ERP component found at occipital electrode sites, significantly distinguished between matching and non-matching angry and fearful facial and bodily expressions. Besides emphasizing the close relationship between processing facial and bodily expressions, these findings additionally suggest that emotional expressions of both faces and bodies are encoded within a very early stage of processing even before the visual categorization of faces and bodies and their recognition of personal identity have taken place as indexed by the time course of the N170/M170 component (Bentin et al., 1996; Eimer, 2000a; Gliga and Dehaene-Lambertz, 2005; Kloth et al., 2006; Liu et al., 2002; Stekelenburg and de Gelder, 2004; Thierry et al., 2006). Faces or bodies which were presented in isolation as control conditions, did not elicit early emotion effects on the P1 component, contrary to expectations. A possible explanation for the absence of effects may be that two negative emotions (fear and anger) were compared, a comparison which also fails to reveal emotion effects in facial expression studies (Balconi and Pozzoli, 2003; Batty and Taylor, 2003; Esslen et al., 2004). When emotional expressions are compared to neutral expres-

sions however, facial expression studies do show rapid electrophysiological emotion effects as indexed by the P1 component (Batty and Taylor, 2003; Eger et al., 2003; Pourtois et al., 2005; Righart and de Gelder, 2006; Williams et al., 2006) and the simultaneously elicited frontal N1 component (Eimer et al., 2003; Holmes et al., 2003).

The EEG study by Stekelenburg and de Gelder (2004) provided the first direct comparison of the electrophysiological correlates associated with the visual encoding of neutral and fearful facial and bodily expressions. They revealed effects of fearful expression for face (left N170 amplitude enhanced for fear) and body stimuli (VPP amplitude enhanced for fear) in the same time window, suggesting similar underlying neuronal mechanisms for the processing of facial and bodily expressions of emotion during the structural encoding stage (Bentin et al., 1996; Eimer, 2000a). A possible confounding variable may however have accounted for the observed body emotion effects. This previous study presented still images of fearful and neutral bodies (faces blurred) in which the fearful bodies were rather dynamic (i.e. a defensive retreating body movement), whereas the neutral instrumental actions were rather static, i.e. the actor did not show any forward or backward whole body movement, known to induce ERP effects (Wheaton et al., 2001), but only an action involving the upper body (e.g. combing hair, drinking from a glass, holding a telephone). This raises the possibility that the observed body emotion effect may have resulted from the differences in perceived implicit movement, instead of the presence of emotion per se. The present study was set up to exclude these possible confounding effects of perceiving implicit body action by controlling explicitly for the same instrumental action and directed whole body movement.

Stimulus material was adapted from a validated stimulus set previously used in a brain imaging study by Grèzes et al. (2007). We used static images extracted from dynamic clips showing actors performing an instrumental action (opening and closing a door) with and without a fearful expression (Fig. 1A). By explicitly controlling for the presence of the same instrumental action in the two conditions we now increase the sensitivity to emotion effects elicited by bodily expressions. We used a Catch-trial detection task in order to make sure that participants maintained attention to perceive all the stimuli, without directing attention on any of the stimulus attributes, while at the same time keeping trials free from motor response contaminations. As early emotion effects on the P1 component have been revealed for faces (Batty and Taylor, 2003; Eger et al., 2003; Esslen et al., 2004; Pourtois et al., 2005) and for face-body-congruency (Meeren et al., 2005), our EEG-analyses are primarily aimed at this early ERP component, on which we now expect to find an effect of body fear. In addition, the ERP components reflecting structural encoding (Bentin et al., 1996; Eimer, 2000a), i.e. the N170 and the VPP, that have previously been shown to be sensitive to emotion effects (Batty and Taylor, 2003; Rossignol et al., 2005; Stekelenburg and de Gelder, 2004) were investigated.

As the P1 component is highly sensitive to the physical characteristics of the stimulus (i.e. a so-called exogenous component, e.g. Johannes et al., 1995; Kenemans et al., 2000) we took great care to minimize possible differences in low-level features between the fear and neutral condition by matching as good as possible all visible features, such as actor, amount of door

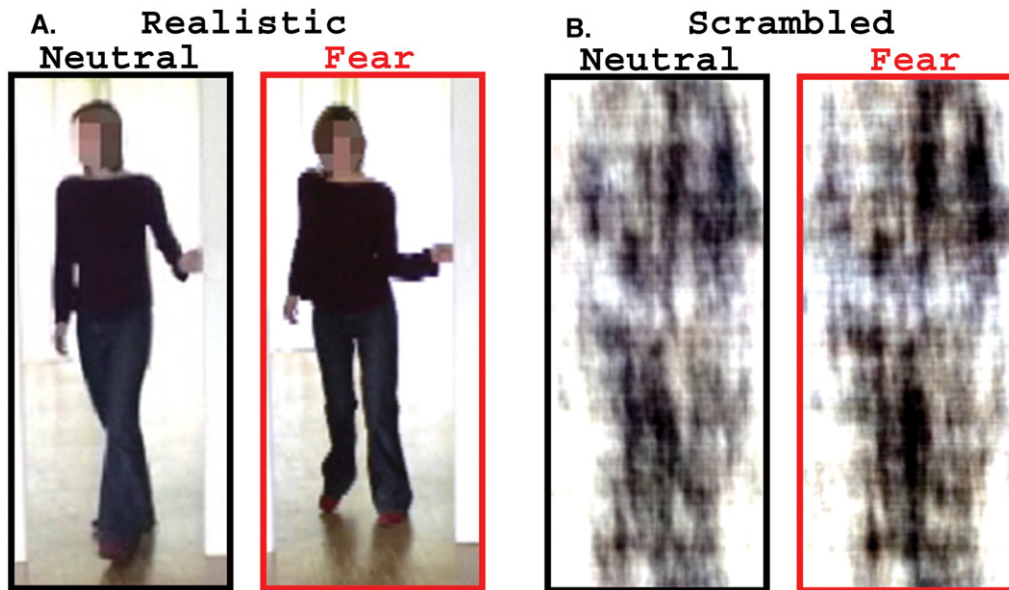


Fig. 1 – Stimulus examples of all four conditions. (A) Realistic: Neutral and Fear, (B) Scrambled (Fourier phase-randomized low-level controls): Neutral and Fear.

opening and configuration and visibility of body parts. In addition we tested whether the low-level stimulus properties of the images would induce condition-related differences in P1 amplitude or latency. To this end we measured ERPs to phase-scrambled versions of the original images, which contain the same spatial frequencies, luminance and contrast as their originals (Fig. 1B).

2. Results

Participants responded with an accuracy of 100% to the Catch-trials without any false alarms. It can therefore be assumed

that sufficient attention was directed toward the stimuli to encode and process them.

The temporal and spatial distribution of the ERPs associated to the realistic images (Figs. 2 and 3) was similar to distributions found in other EEG studies on visual body and face perception (Meeren et al., 2005; Stekelenburg and de Gelder, 2004). Between 80 and 140 ms PSO an occipito-temporal positive potential, the P1, was observed (Fig. 2). This component was also visible for the scrambled images, although peaking slightly later between 90 and 150 ms PSO (Fig. 2). Subsequently an occipito-temporal negative deflection, the N170, and a vertex positive potential, the VPP were encountered within the time window of 140–230 ms PSO (Fig. 3) when subjects viewed

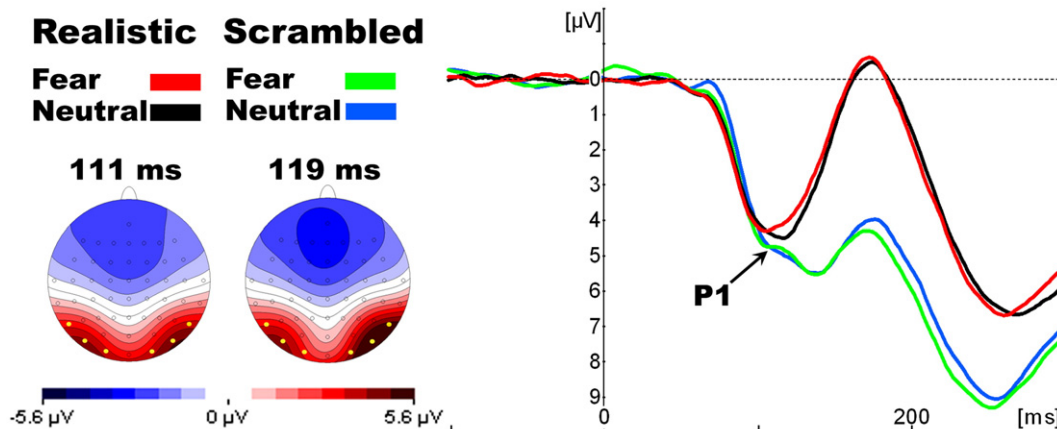


Fig. 2 – Representation of the P1 component of the realistic and the scrambled images. Left: Scalp distributions of the P1 peak amplitudes to the Fear conditions for the realistic (left) and the scrambled (right) images, corresponding to latencies of 111 and 119 ms post stimulus onset respectively. Yellow dots indicate the electrode group analyzed. Right: Grand-averaged time course of the P1 ERP component is given for Realistic Neutral (black), Realistic Fear (red), Scrambled Neutral (blue) and Scrambled Fear (green), pooled over their analyzed electrodes, with the P1 component indicated with an arrow. These data represent a group of 13 participants.

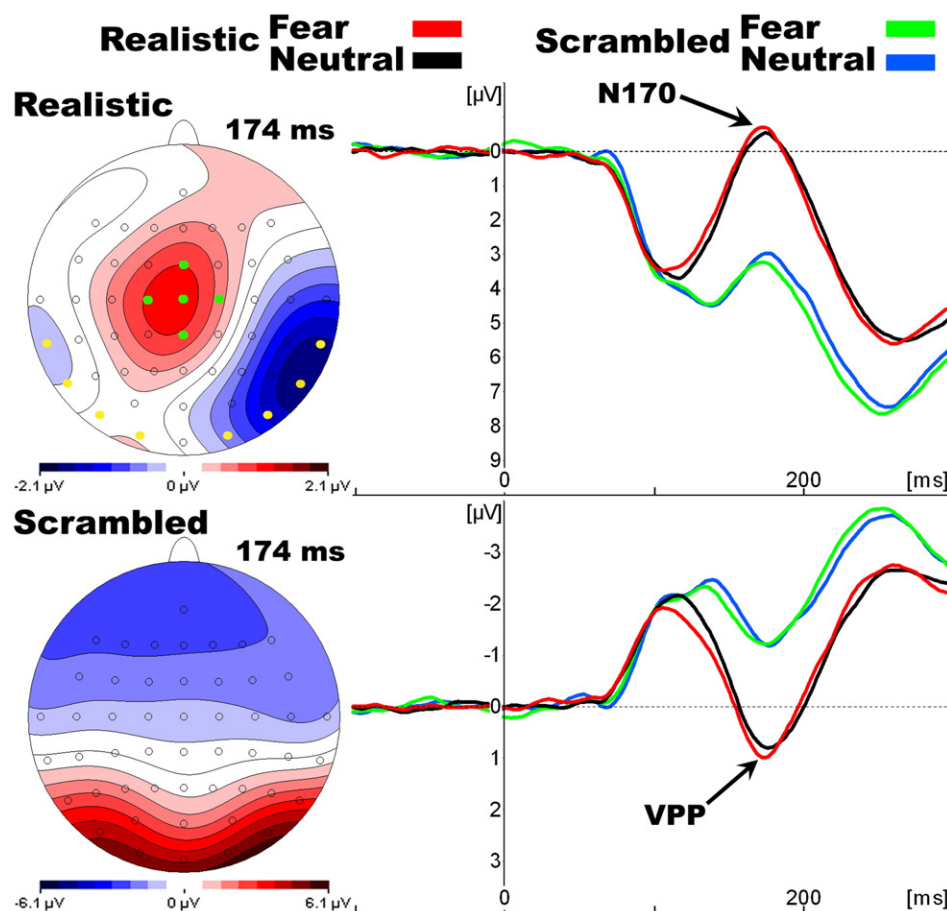


Fig. 3 – Representations of the N170 and VPP components elicited by realistic and scrambled images. **Left:** Scalp distributions of the peak amplitudes to the Fear condition for the realistic (top) and the scrambled (bottom) images, corresponding to a latency of 174 ms post stimulus onset. Dots indicate the electrode group analyzed for the N170 component (yellow) and the VPP component (green). **Right:** Grand-averaged time course of the N170 (top) and the VPP (bottom) components is given for Realistic Neutral (black), Realistic Fear (red), Scrambled Neutral (blue) and Scrambled Fear (green), pooled over the analyzed electrode group, with the component indicated with an arrow. These data represent a group of 13 participants.

the realistic images. Such a typical N170/VPP complex was absent in the ERPs associated to the scrambled images; around this latency the deflections showed a different topographical distribution and were of opposite polarity (Fig. 3), and were not further quantified.

Quantitative information and GLM results concerning the ERP components elicited by the realistic images can be found in Table 1. For the P1 amplitude and latency analyses we used the following Within Subjects Factors: Electrode Site (three levels, i.e. Occipital (O1/2), Parieto-Occipital (PO7/8) and Parietal (P7/8)), Hemisphere (two levels, i.e. Left and Right) and Emotion (two levels, i.e. Fear, Neutral) separately for the realistic and the scrambled images. Analyzing the P1 associated with the realistic images we found a main Emotion effect for the P1 latency [$F(1,12)=9.87$, $P<.01$] with Fear (111 ms) reaching P1 peak maximum earlier as compared to Neutral (114 ms) (see also Fig. 2 and Table 1). P1 amplitude analysis did not reveal any Body Emotion effects, but only a main effect of Electrode Site [$F(2,11)=23.01$, $P<.0005$, with Parieto-Occipital>Occipital>Parietal] and Hemisphere [$F(1,12)=8.46$, $P<.05$,

with Right>Left]. In addition, a significant interaction effect between these two factors was found [$F(2,11)=5.73$, $P<.05$], with post hoc tests only showing an absence of the Hemisphere difference at the Occipital electrodes. To test the effects of the basic visual properties of the stimuli, we subjected the

Table 1 – ERP components elicited by the realistic images

Component	Body emotion	Amplitude (μV)	Latency (ms)
P1	Neutral	5.71 ± 0.62	$114.0 \pm 4.5^{**}$
	Fear	5.53 ± 0.57	$110.6 \pm 4.4^{**}$
N170	Neutral	-1.35 ± 0.68	176.0 ± 4.7
	Fear	-1.38 ± 0.68	174.5 ± 4.6
VPP	Neutral	1.11 ± 0.33	$179.6 \pm 4.0^*$
	Fear	1.22 ± 0.35	$175.0 \pm 3.1^*$

Amplitude (μV) and latency (ms) values (mean \pm SEM, $n=13$) of the investigated ERP components on relevant electrode groups elicited by the realistic images. The significance levels resulting from the GLM analysis are indicated by stars, with $^*P<.05$ and $^{**}P<.01$.

Table 2 – P1 component elicited by the scrambled images

Component	Stimulus condition	Amplitude (μ V)	Latency (ms)
P1	Scrambled Neutral	6.71 \pm 0.93	121.9 \pm 5.4
	Scrambled Fear	6.67 \pm 0.97	119.8 \pm 5.5
Amplitude (μ V) and latency (ms) values (mean \pm SEM, $n=13$) of P1 ERP component on relevant electrode groups elicited by the scrambled images. The two conditions did not differ from each other according to the GLM analysis, i.e. $P>.05$.			

amplitude and latency of the P1 component elicited by the scrambled images to a separate analysis of variance using the GLM with the same Within Subject Factors as for the realistic images (see Table 2). No differences between the Scrambled Neutral and Fear conditions were revealed, neither for peak amplitude ($F<1$) nor latency ($F<1$).

For the analysis of the N170 the following Within Subjects Factors were used: Electrode Site (four levels: Occipital (O1/2), Parieto-Occipital (PO7/8), Parietal (P7/8), Temporo-Parietal (TP7/8)), Hemisphere (two levels; Left and Right) and Emotion (two levels, i.e. Fear, Neutral). No main or interaction effects were found for the factor Emotion on either amplitude or latency. The only significant effect found was a main effect of Electrode Site on the N170 latency [$F(3,10)=6.12$, $P<.05$; Parieto-Occipital<Parietal<Temporo-Parietal<Occipital], with post hoc tests revealing significant latency differences between the Occipital (179.1 ms) and Parieto-Occipital (171.2 ms) [$t(1,12)=3.23$, Bonferroni corrected $P<.05$] and between the Parietal (171.8 ms) and the Temporo-Parietal (178.9 ms) [$t(1,12)=3.65$, Bonferroni corrected $P<.05$] electrodes. None of the factors had an effect on the N170 amplitude.

Analyses of the VPP amplitude and latency used Electrode Site (five levels, i.e. FCz, C1, Cz, C2, CPz) and Emotion as Within Subjects Factors. A significant main effect of Emotion on the VPP latency [$F(1,12)=6.14$, $P<.05$] was found, with Fear (175 ms) showing a faster latency as compared to Neutral VPP peak latency (180 ms) (see also Fig. 3 and Table 1). No other effects were revealed.

3. Discussion

Our goal was to further investigate the electrophysiological correlates associated with perceiving fearful body expressions. Using EEG we investigated the early temporal dynamics of perceiving implicit instrumental body action performed with and without a fearful expression. By explicitly controlling for the presence of the same implicit instrumental body movement, i.e. opening a door, and the direction of whole body movement, we enhanced the emotion sensitivity of our design as compared to the study of Stekelenburg and de Gelder (2004), and found faster processing of fear signals as compared to neutral signals for two early ERP components, i.e. the P1 component around 110 ms and the vertex positive potential around 175 ms post stimulus onset (PSO). The present results provide support for our hypotheses of rapid neural mechanisms for the perceptual processing of fear signals expressed by the body similar as what has been found for faces.

3.1. Fear expression in the body affects the P1 latency

With the present emotion sensitive design we found an early electrophysiological body emotion effect on the P1 component for the first time, with faster latencies for fearful bodies (110.6 ms) than for neutral bodies (114.0 ms). In order to be able to establish a true emotion effect however, it is of prime importance to exclude the possibility that systematic differences in low-level attributes between the fear and neutral condition may have caused the observed effect. As the early exogenous P1 component is extremely sensitive to the physical properties of the stimulus, these may easily confound the results. We ruled out this possibility by a priori matching the fear and neutral stimuli with respect to actor, direction of whole body movement, configuration and visibility of body parts, and amount of door opening. Second, we tested whether the same stimuli would also induce a P1 latency difference after destroying structure and meaning from the images but leaving intact their low-level attributes. The fact that phase-scrambling abolished the condition-specific effect on the P1 latency strongly suggests that the observed effect was indeed caused by the expressed emotion.

This early latency effect at 110 ms after picture onset demonstrates that the perceptual processing of fear signals conveyed by the body, is already initiated at the earliest stage of visual processing, even before an abstract recognition of the human body form, comparable to the structural encoding process of the face (Bruce and Young, 1986), thought to take place in the time window of the N170 component (e.g. Bentin et al., 1996; Thierry et al., 2006), has been completed. This early effect on the P1 possibly reflects an early visual mechanism of rapid emotion detection based on crude visual cues in the body and face.

Until recently the P1 was considered only to index the processing of basic visual features. There is now growing evidence however that this early component and its neural generator are already associated with forms of higher-order face processing such as face detection within a noisy image (Liu et al., 2002), facial attractiveness (Pizzagalli et al., 2002) and face inversion (Itier and Taylor, 2002, 2004b,c; Itier et al., 2006; Linkenkaer-Hansen et al., 1998).

The present findings are the first direct evidence that higher-order information from the body is already processed at the stage of P1. In our previous work we already found an indication for the existence of a rapid neural processing mechanism for the processing of bodily emotion (Meeren et al., 2005) by showing an effect on the P1 amplitude for the emotional congruency between facial and bodily expression. In this respect, there appear to be relatively similar early neural processing mechanisms dedicated to the perception of fear expressions in bodies and faces, as fearful expression conveyed by the face has repeatedly been found to affect the P1 component (Batty and Taylor, 2003; Eger et al., 2003; Pourtois et al., 2005; Righart and de Gelder, 2006; Williams et al., 2006). The former is however in contrast with the processing of other affective stimuli such as emotional scenes (Righart and de Gelder, 2006) or negatively conditioned gratings (Keil et al., 2002) which affect other ERP components than the P1.

The fact that bodily fear did not affect the P1 amplitude but only its latency, suggests that fear signals from the body do

not recruit more brain resources at this stage, but exert their influence by slightly speeding up visual processing. The latter may point to slight differences compared to the exact neural mechanisms underlying the processing of fear expressed in the face, which has been found to both affect P1 latency and amplitude.

3.2. *Fear expression in the body affects the VPP latency, not the N170*

In line with previous EEG studies on body recognition (Glignani and Dehaene-Lambertz, 2005; Meeren et al., 2005; Stekelenburg and de Gelder, 2004; Thierry et al., 2006), a prominent N170/VPP complex was elicited by perceiving bodies in the present study. The fact that this was encountered yet with another stimulus set and another task demonstrates the robustness of the body N170 and VPP components and suggests similar structural encoding dynamics for bodies as previously proposed for faces (Bentin et al., 1996; Eimer, 2000a; Stekelenburg and de Gelder, 2004; Thierry et al., 2006). The finding that these components were abolished after phase-scrambling shows the sensitivity of the N170/VPP for higher-order visual processing.

The well-known N170 elicited during face perception is thought to reflect a late stage in structural encoding, i.e. the visual analysis of features that leads to the categorization of a pictorial stimulus as a face (Bentin et al., 1996; Bruce and Young, 1986; Eimer, 2000a). Moreover, magnetoencephalographic studies suggest that this stage is also associated with the process of personal identity recognition (Kloth et al., 2006; Liu et al., 2002). Source localization studies investigating the face-responsive N170/VPP complex (Botzel et al., 1995; Halgren et al., 2000; Itier and Taylor, 2004a; Linkenkaer-Hansen et al., 1998; Rossion et al., 2003; Shibata et al., 2002), have located its neural generators within the middle fusiform gyrus, the lateral/inferior occipital cortex, or the superior temporal sulcus (STS). The same areas have also been found to hemodynamically respond to faces and emotional expressions therein (Dolan et al., 2001; Kanwisher et al., 1997; Schwarzlose et al., 2005; Spiridon et al., 2006; Streit et al., 1999). Likewise, activation of the lateral occipital cortex and the middle fusiform gyrus has recently also become firmly established during the visual perception of bodies (Grossman and Blake, 2002; Peelen and Downing, 2005; Schwarzlose et al., 2005; Spiridon et al., 2006), while activity in the middle fusiform gyrus has proved to be strongly modulated by fear expressed in the body (de Gelder et al., 2004; Hadjikhani and de Gelder, 2003; Van de Riet et al., submitted for publication).

Consistent with our previous ERP work on body expression (Stekelenburg and de Gelder, 2004), and the majority of facial expression studies (e.g. Ashley et al., 2004; Eimer and Holmes, 2002; Eimer et al., 2003; Esslen et al., 2004; Holmes et al., 2003; Krolak-Salmon et al., 2001) the present N170 component was not affected by fear expressed in the body. In contrast, the positive counterpart of the N170, the VPP – presumably generated by the same neuronal source as the N170 (Joyce and Rossion, 2005) – did show to be sensitive to the fearful body expression. This was evidenced by faster VPP latencies for fear as compared to neutral bodies while the VPP amplitude was unaffected. This differs from our earlier finding of larger VPP

amplitudes for fear as compared to neutral bodies (Stekelenburg and de Gelder, 2004). Two important methodological improvements may account for this discrepancy: In the present study conditions were matched for the implicit instrumental body action (opening a door) and for several high-level (actors, configuration and visibility of body parts) and low-level features (amount of door opening, doorway centering), and as a result the interstimulus perceptual variance (ISPV) was minimized and equal for the two conditions.

With respect to higher level visual processing it appears that latency effects as found in the present study are more robust than amplitude effects. For example, among numerous ERP studies face inversion invariably causes a delay in the N170, whereas an enhancement of the N170 amplitude cannot always be found (e.g. Bentin et al., 1996; Boutsen et al., 2006; Rossion et al., 2003). Moreover, recently it was found that whereas the N170 amplitude is strongly affected by the ISPV, the N170 latency is not (Thierry et al., 2007). In fact, the N170 latency appears to be more sensitive to stimulus category than the N170 amplitude (Thierry et al., 2007). This sheds an interesting light on our previous and present findings. In our previous study on fear bodies, the amplitude of the vertex positive counterpart of the N170 was larger for fearful than for neutral bodies (Stekelenburg and de Gelder, 2004). This effect may be explained by uncontrolled systematic differences in ISPV with lower ISPV for the fear bodies than for the instrumental neutral bodies for which pictures were shown of people in all different postures and positions. Indeed, in the present study now that ISPV is minimized and similar for the two conditions, the previously found VPP amplitude effect is abolished. Instead, we now find an effect on the VPP latency with fear bodies being processed slightly but significantly faster than the neutral bodies.

3.3. *Concluding remarks*

Using EEG we investigated the early temporal dynamics of perceiving fear signals conveyed by the body. As a methodological improvement to our previous work on emotional body perception we enhanced the sensitivity of our design to possible emotion effects by explicitly controlling for the presence of implicit instrumental movement (i.e. opening a door), the direction of body movement, and several low-level features.

We found faster processing of fearful body expression as compared to neutral body expression for two early ERP components, i.e. the P1 component around 110 ms and the VPP component around 175 ms PSO. The present results provide the first experimental evidence for the existence of a rapid neural mechanism for the perceptual processing of fear signals expressed by the body, as previously found for faces. These findings argue against the sequential processing of emotional expression only after structural encoding has taken place, as proposed by earlier face processing models (Bruce and Young, 1986). Instead it points to the early processing of emotion expression in parallel to the visual analysis that leads to the categorization of a stimulus as a body. We do not want to claim that the full emotional meaning of the body images is already processed and recognized at that time. Our results only demonstrate that the condition-specific information

concerning the emotion displayed in the different stimulus categories is processed. Further research is needed to explore the influence of various context factors on the processes whereby full understanding of the emotional expression is achieved (Barrett et al., 2007; de Gelder et al., 2006) and in which subjective emotional experience is grounded. Whether the observed effect for fear also pertains to other negative (e.g. anger, disgust) and/or positive (e.g. happy) emotions, or is a reflection of fear-specific processing mechanisms remains to be investigated in future studies.

4. Experimental procedures

4.1. Participants

Seventeen healthy right-handed individuals (mean age 24 years, range 19–45 years; seven males) with normal or corrected to normal vision volunteered to take part in the experiment, after giving their informed consent. The participants were rewarded for their services with course credits or financial compensation. The study was performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

4.2. Stimulus material

Using image and graphics editing software, static body stimulus material was extracted from short (3 s) colored video fragments of four male and four female actors opening and closing a door, in a neutral or fearful expression, used and described by Grèzes et al. (2007). The semi-professional actors were instructed by a professional director to enact different scenarios corresponding to neutral and fearful situations. All stimuli have previously been validated using a forced-choice emotion categorization task with fear, anger or neutral as possible answers. The average recognition rate for the Fear video fragments was 86%, for the Neutral video fragments 97% (Grèzes et al., 2007). The moment in time at which these Fear video fragments reached their emotional apex was defined for each actor individually. These apex bitmaps were used as static Fear images in the present experiment. For each actor, a corresponding Neutral image was extracted from the Neutral video fragments that matched as good as possible the amount of door opening, configurations of head, trunk, arms and legs, direction of whole body movement and visible body parts. Next, the corresponding Fear and Neutral images were computer edited such that their physical properties matched as closely as possible, e.g. the doorway was centered and made of equal size. In addition, we created scrambled control stimuli of the Fear and Neutral images that contain the same spatial frequencies, luminance and contrast as their originals, but have lost all structure and meaning. To this end, all bitmaps were phase-scrambled using a two-dimensional Fast Fourier transform (FFT). After randomizing the phases, scrambled images were constructed using the original amplitude spectrum. Summing up, this resulted in a total of 32 images, i.e. 16 realistic images of eight actors opening a door in a fearful and a neutral fashion and their 16 scrambled counterparts (Fig. 1).

4.3. Procedure

The experiment was conducted in an electrically shielded, sound-attenuating room. Subjects were comfortably seated in an armchair with their eyes at about 90 cm distance from the computer monitor. The size of the stimuli on screen ranged between 3.3×10.2 cm and 4.7×11.5 cm (respectively corresponding to 2.1° – 3.0° horizontal \times 6.5° – 7.3° vertical visual angles). The experiment consisted of two blocks; each lasting about 11 min, with 192 randomly presented trials per block. Each block included one Catch-trial per stimulus variation in addition to five repetitions of every stimulus variation (ratio Catch-trials/Experimental-trials is 1:5). To familiarize the subjects with the procedure and task demands the experiment was preceded by a short training session which contained samples of all stimulus categories.

To minimize eye blinking during baseline and stimulus presentation, each trial started with a blink instruction lasting 700 ms (a representation of a closed eye on a black background ($=2.5^\circ$ horizontal \times 0.9° vertical visual angles)) at the center of the screen. Participants were instructed to blink at this point in time, when they needed to. A fixation mark followed, consisting of a black 'plus' sign ($=1.0^\circ$ horizontal and vertical visual angles) on a grey background ($=3.0^\circ$ horizontal \times 7.3° vertical visual angles) also presented at the center of the screen. This fixation mark was presented with a random duration between 1200 ms and 1700 ms after which the experimental stimulus (2.1° – 3.0° horizontal \times 6.5° – 7.3° vertical visual angles) was presented for 700 ms. A black screen lasting 500 ms, during which subjects were allowed to respond when required, followed the stimulus presentation. The next trial followed immediately thereafter. The participants were asked to only respond to the Catch-trials as accurately and as fast as possible using a right-hand-controlled response box. The Catch-trials (a white star, 1.5° horizontal and vertical visual angles) were presented at the center of the screen, superimposed onto the experimental stimulus, with a duration of 200 ms and a variable onset latency ranging between 80 ms and 400 ms after the onset of the experimental stimulus.

4.4. EEG recording

EEG was recorded from 50 scalp sites using active Ag–AgCl electrodes (BioSemi Active-Two, BioSemi Inc., Amsterdam, The Netherlands) mounted in an elastic cap, referenced to an additional active electrode (Common Mode Sense). EEG signals were band-pass filtered (0.1–40 Hz, 24 dB/octave), and digitized at a sample rate of 512 Hz. EOG was registered above and below the left eye and at the outer canthi of both eyes, to enable monitoring of eye movements and eye blinks.

4.5. Data analysis

Off-line the raw EEG data were re-referenced to an averaged reference and segmented into epochs starting 250 ms before to 1000 ms after stimulus onset. The average amplitude of the 100 ms pre-stimulus epoch served as baseline. The data were EOG corrected using the algorithm of Gratton et al. (1983). Segments with an amplitude change exceeding 100 μ V at any channel after EOG correction were rejected from analysis.

Signals were averaged across trials time-locked to the onset of the stimuli for each stimulus category separately, creating the following ERPs: Realistic Fear (RF), Realistic Neutral (RN), Scrambled Fear (SF) and Scrambled Neutral (SN). The following ERP components were identified based upon a tailored selection of electrode sites and their appropriate time window: the P1 (maximal positive deflection between 80 and 150 ms PSO, on electrodes O1, O2, PO7, PO8, P7, P8), N170 (maximal negative deflection between 140 and 230 ms PSO, on electrodes O1, O2, PO7, PO8, P7, P8, TP7, and TP8) and VPP (maximal positive deflection between 140 and 230 ms PSO, on electrodes FCz, C1, Cz, C2, and CPz). In order to prevent the results of the component peak analyses from being contaminated by spurious deflections, only participants showing ERPs with high signal-to-noise components (i.e. with an amplitude higher than twice the maximal pre-stimulus deflection) were included into the peak detection and subsequent analyses, resulting in the inclusion of 13 participants. The peak amplitudes and peak latencies of these ERP components elicited by the realistic images were subjected to analyses of variance for repeated measures using the General Linear Model to reveal Body Emotion effects. For additional post hoc tests, *P*-values were Bonferroni corrected. Within the ERPs related to the scrambled conditions only the P1 could be reliably identified and was subjected to a separate GLM analysis to reveal possible condition specific effects based on low-level physical stimulus properties.

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